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Fukuyama et al.

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(54) **VEHICLE CONTROL DEVICE**

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B60W 60/00 (2020.01)

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CPC ***B60N 2/0244*** (2013.01); ***B60N 2/20*** (2013.01); ***B60W 40/08*** (2013.01); *B60W 2040/0827* (2013.01); *B60W 60/00133* (2020.02); *B60W 2420/403* (2013.01); *B60W 2540/229* (2020.02); *B60W 2552/15* (2020.02); *B60W 2552/30* (2020.02); *B60W 2552/35* (2020.02); *B60W 2556/40* (2020.02)

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See application file for complete search history.

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(57) **ABSTRACT**

A vehicle control device includes a sleep depth estimation unit that estimates a sleep depth of an occupant seated in a seat provided in a vehicle, and a control unit that controls the vehicle such that a magnitude of the external force to be applied to at least one of a plurality of the occupants is equal to or less than a first threshold value when the estimated sleep depth of the occupant is equal to or lower than a predetermined reference depth or when the occupant is awake, and that controls the vehicle such that the magnitude of the external force to be applied to each of all the occupants is equal to or less than a second threshold value larger than the first threshold value when the sleep depth of each of the occupants is greater than the reference depth.

12 Claims, 10 Drawing Sheets

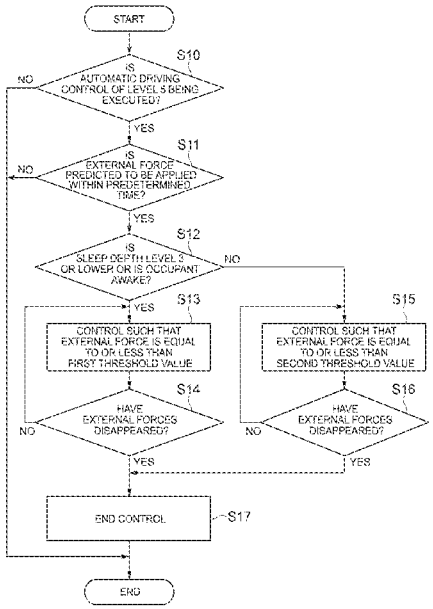

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FIG. 1

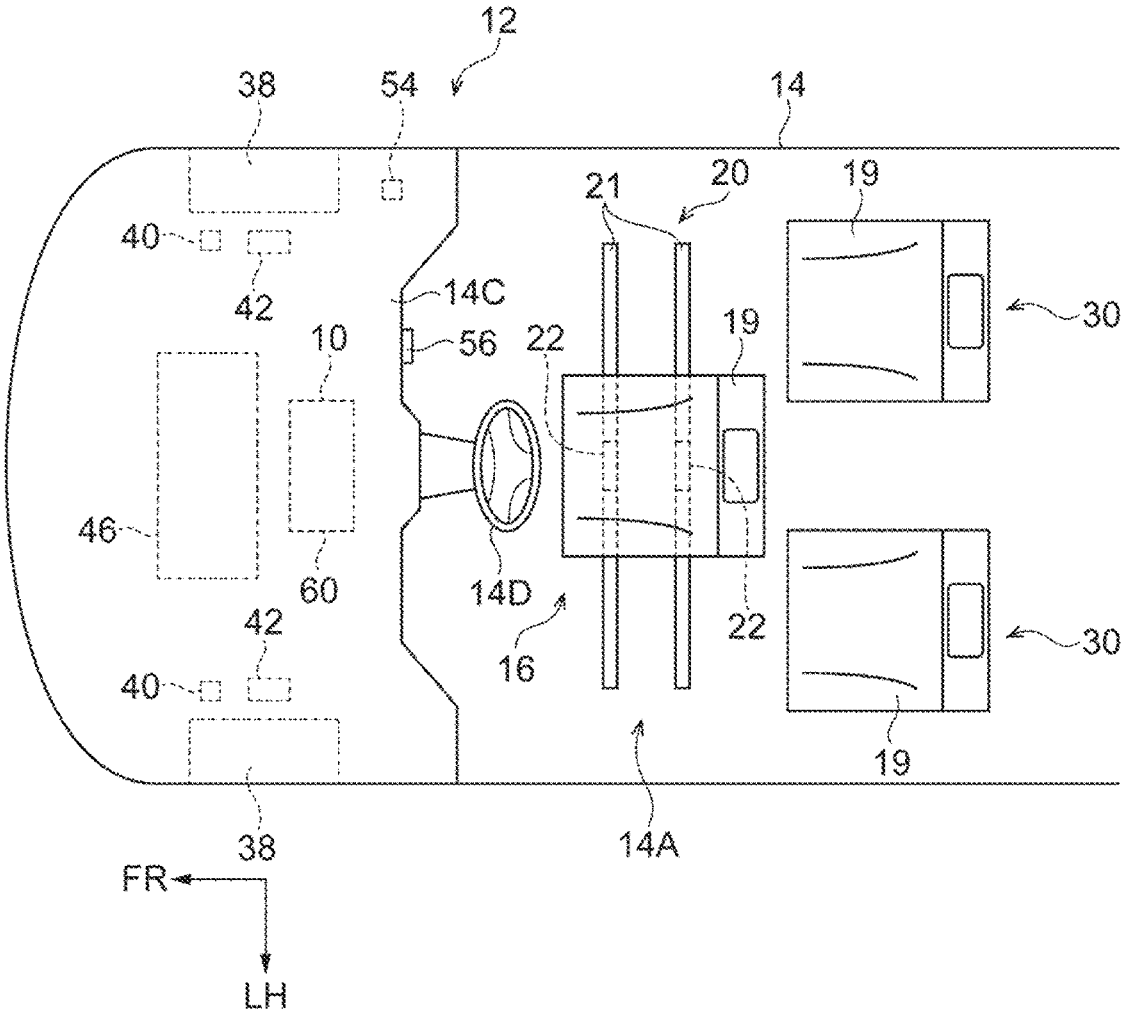

12
38
54
14
21
20
19
40
42
14C
56
22
19
30
10
46
60
14D
16
22
30
42
40
19
38
14A
FR
LH

FIG. 2

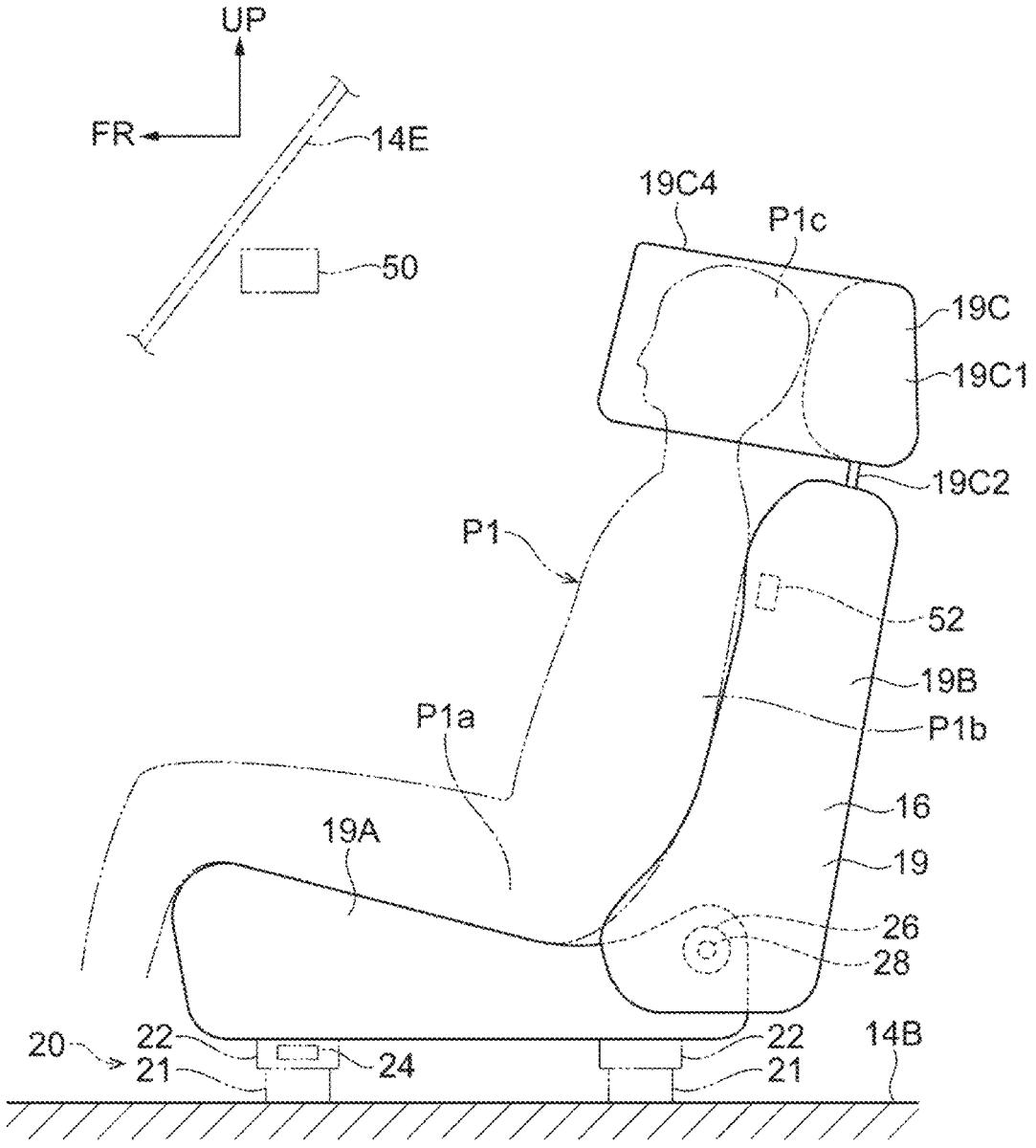

UP
FR
14E
50
19C4
P1c
19C
19C1
19C2
P1
52
19B
P1b
P1a
16
19A
19
26
28
20
22
21
24
22
21
14B

FIG. 3

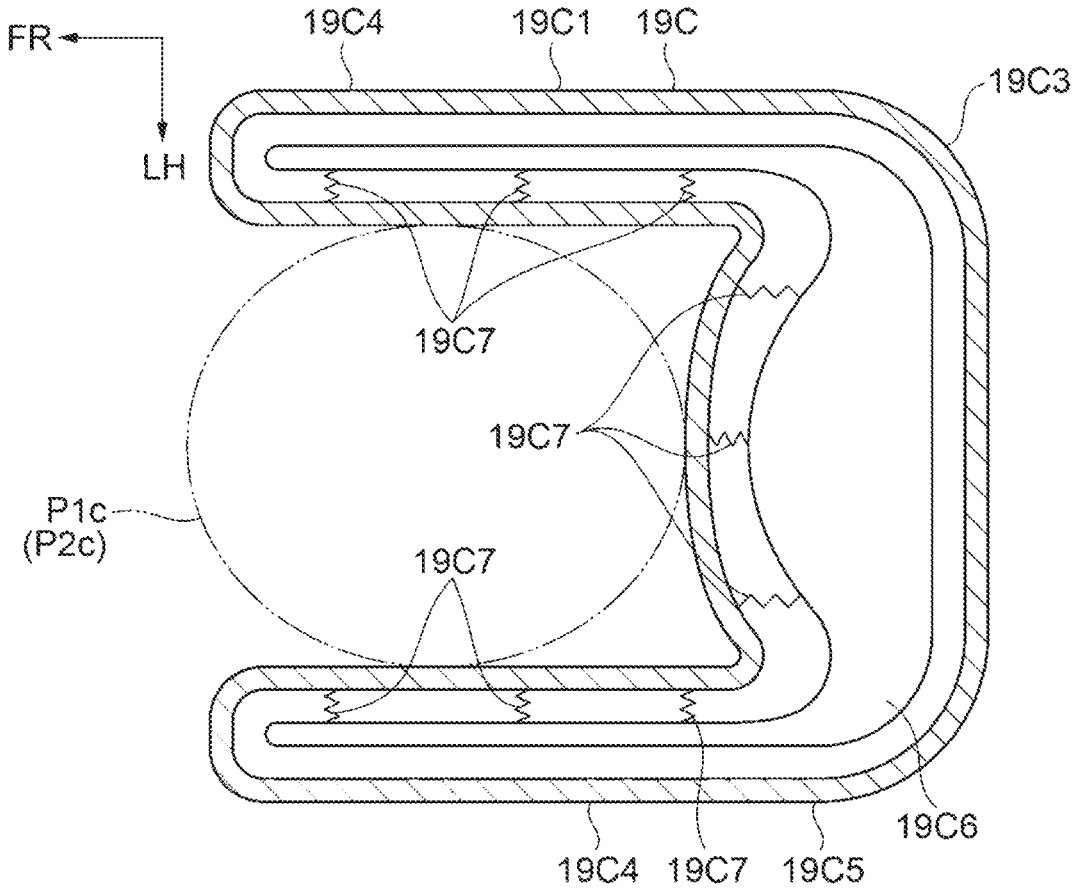

FR
LH
19C4
19C1
19C
19C3
19C7
19C7
19C7
P1c
(P2c)
19C6
19C4
19C7
19C5

FIG. 4

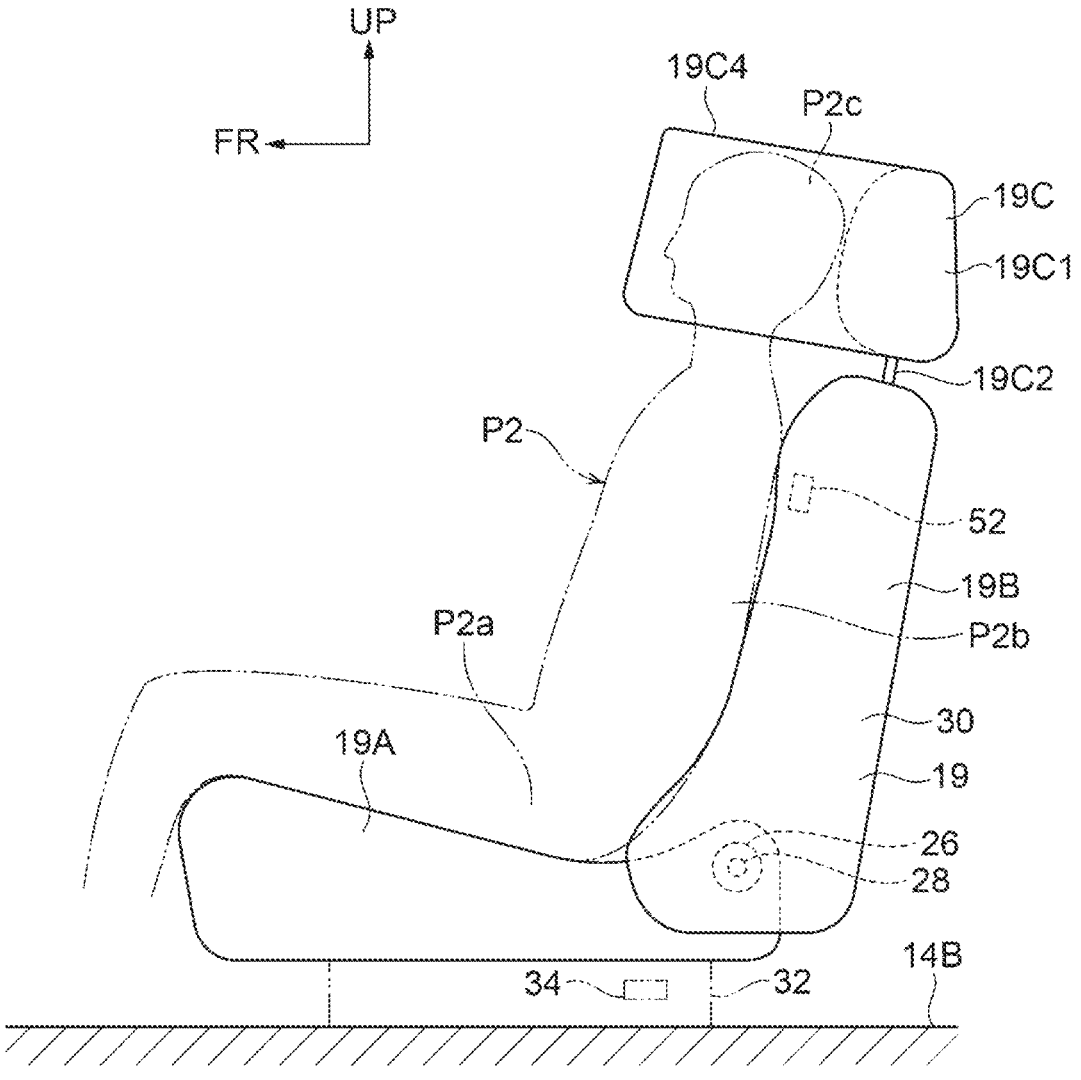

UP
FR
19C4
P2c
19C
19C1
19C2
P2
52
19B
P2b
P2a
30
19A
19
26
28
14B
34
32

FIG. 5

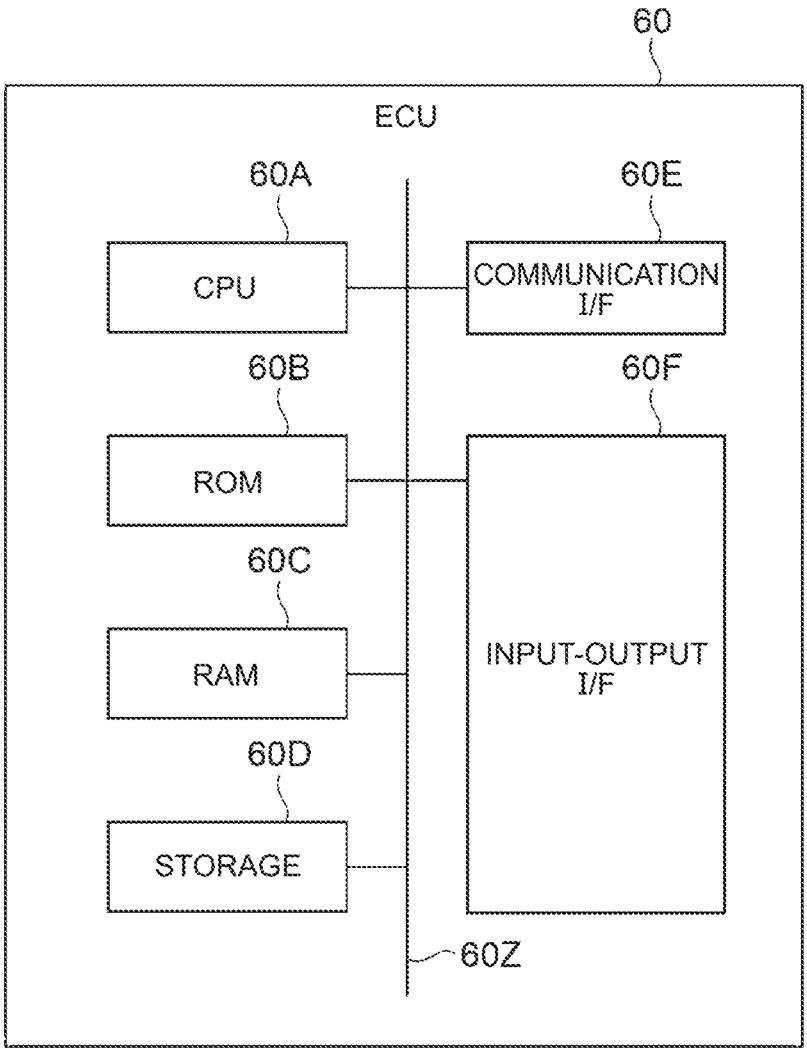

60
ECU
60A
CPU
60E
COMMUNICATION I/F
60B
ROM
60F
60C
RAM
INPUT-OUTPUT I/F
60D
STORAGE
60Z

FIG. 6

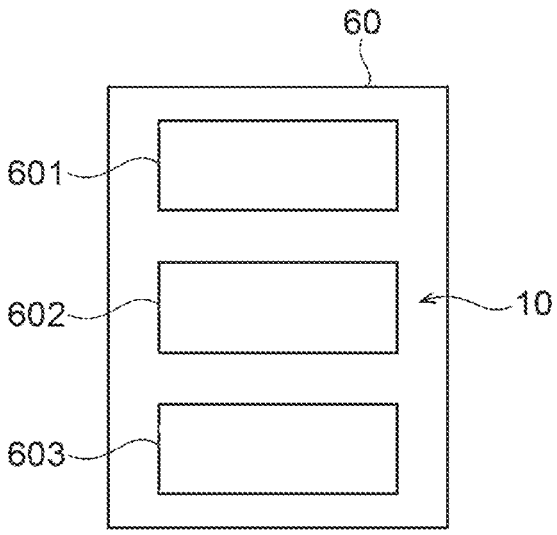


FIG. 7

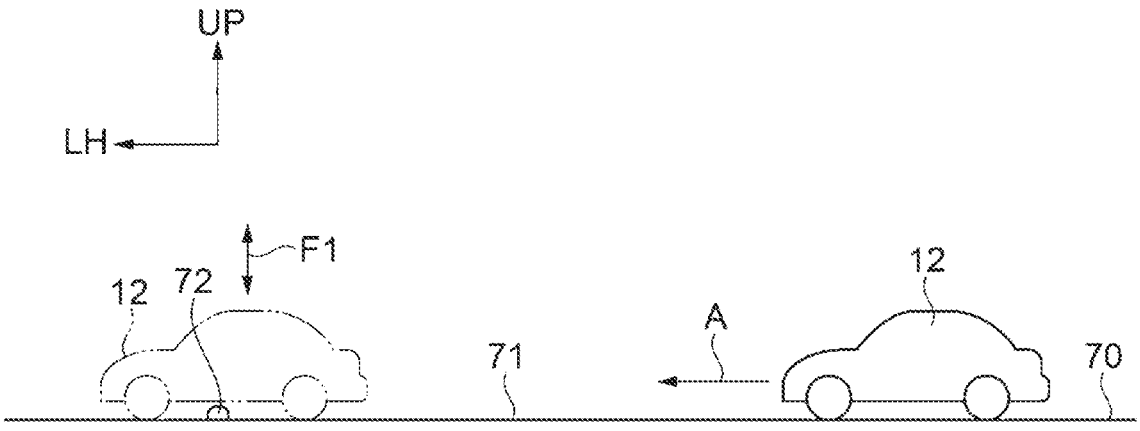


FIG. 8

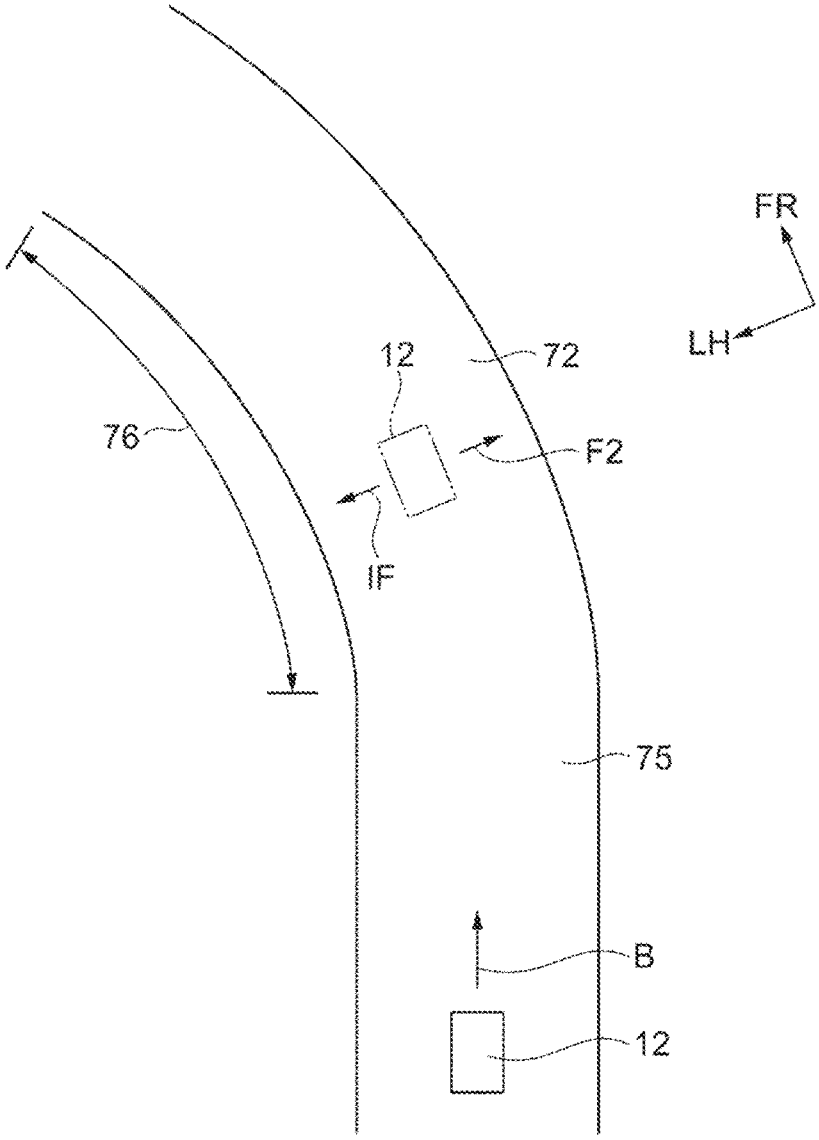


FIG. 9

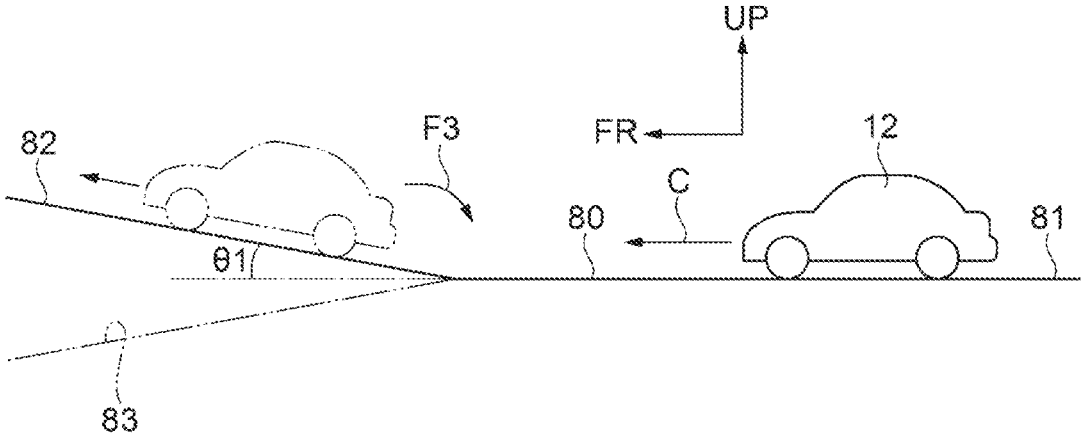


FIG. 10

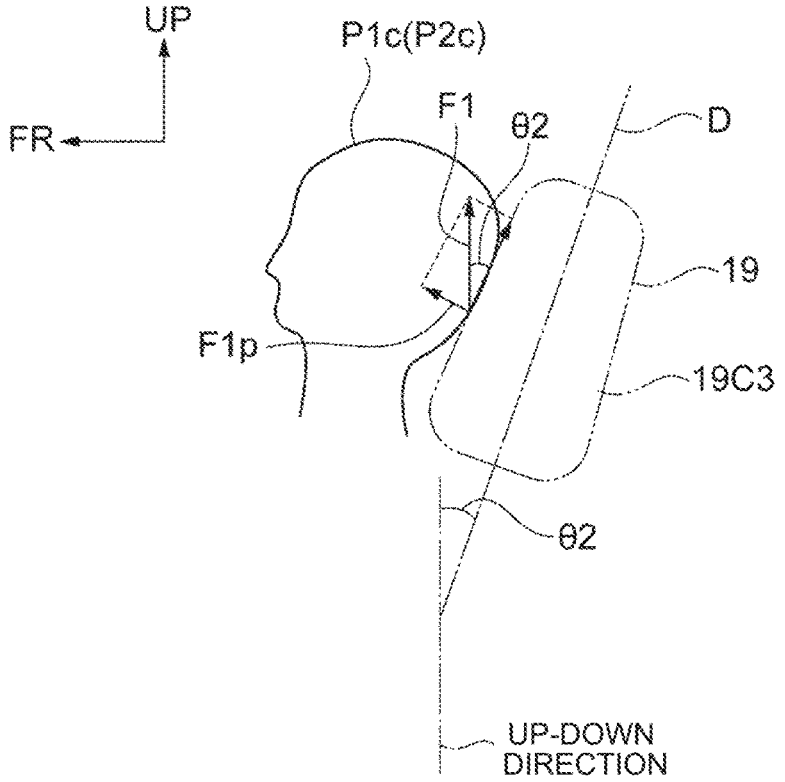

UP
FR
P1c(P2c)
F1
θ2
D
19
F1p
19C3
θ2
UP-DOWN
DIRECTION

FIG. 11

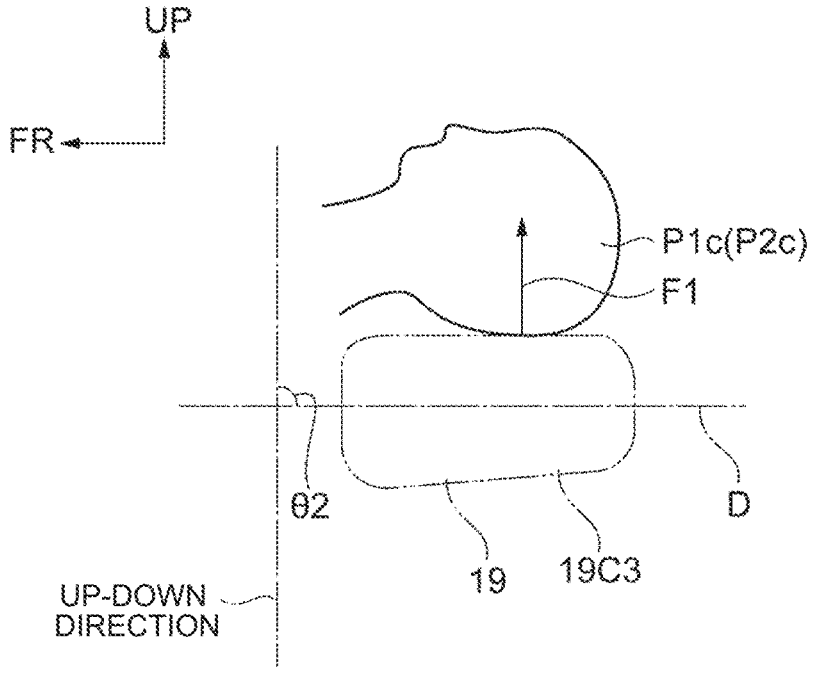

UP
FR
P1c(P2c)
F1
θ2
D
19
19C3
UP-DOWN
DIRECTION

FIG. 12

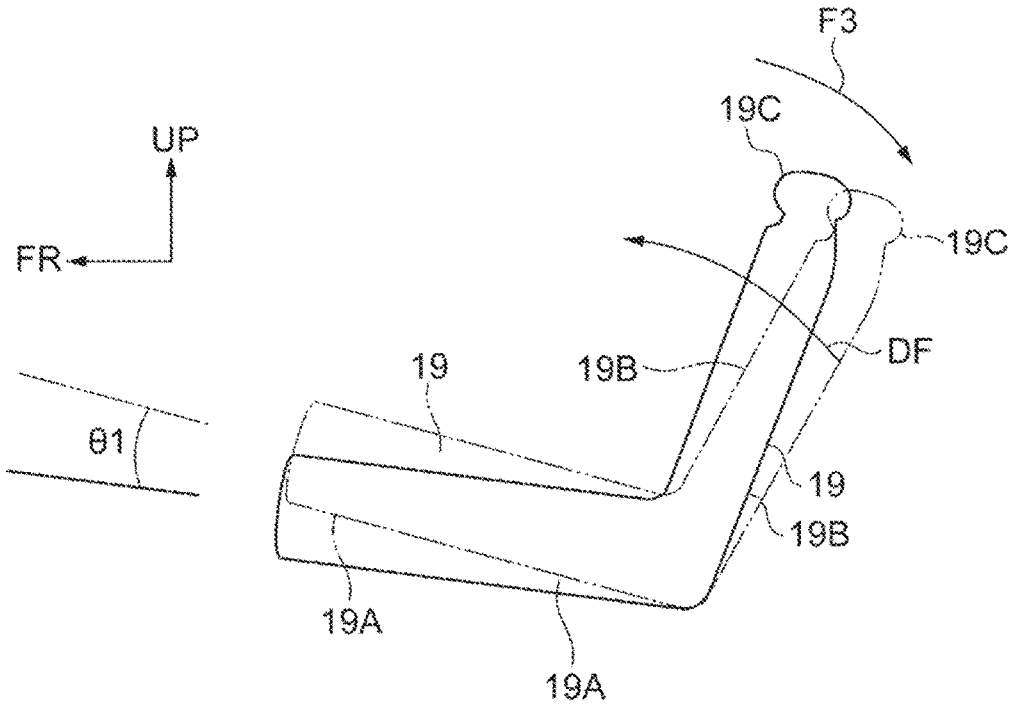

F3
19C
UP
FR
19C
DF
19
19B
θ1
19
19B
19A
19A

FIG. 13

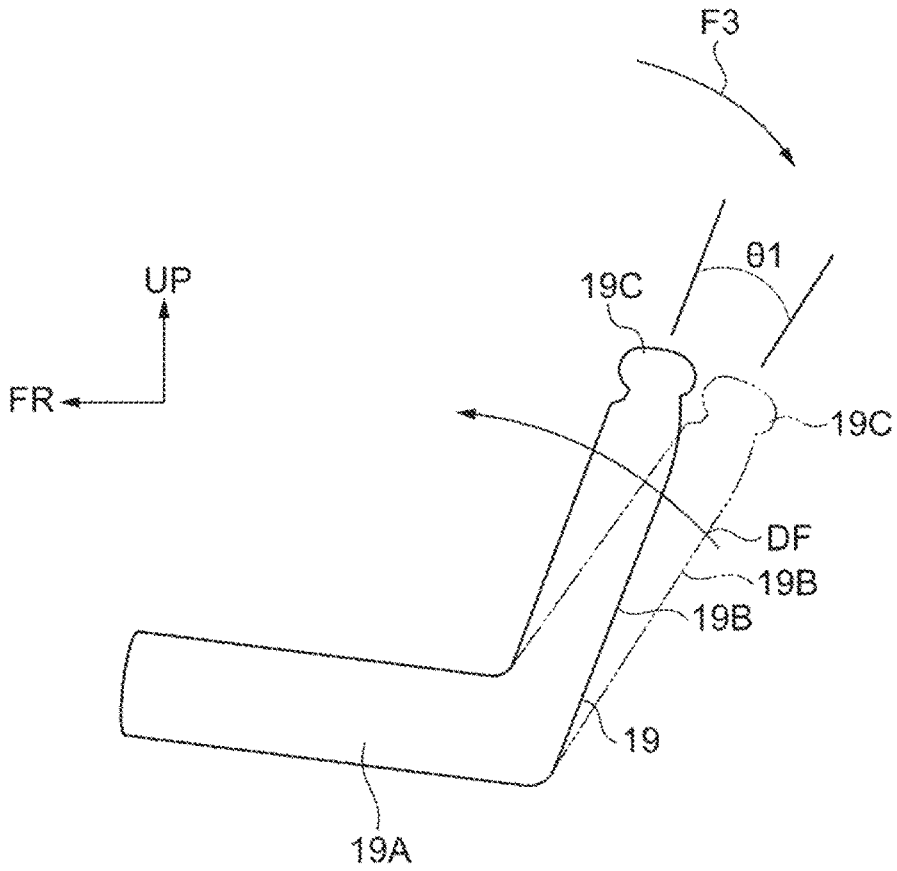
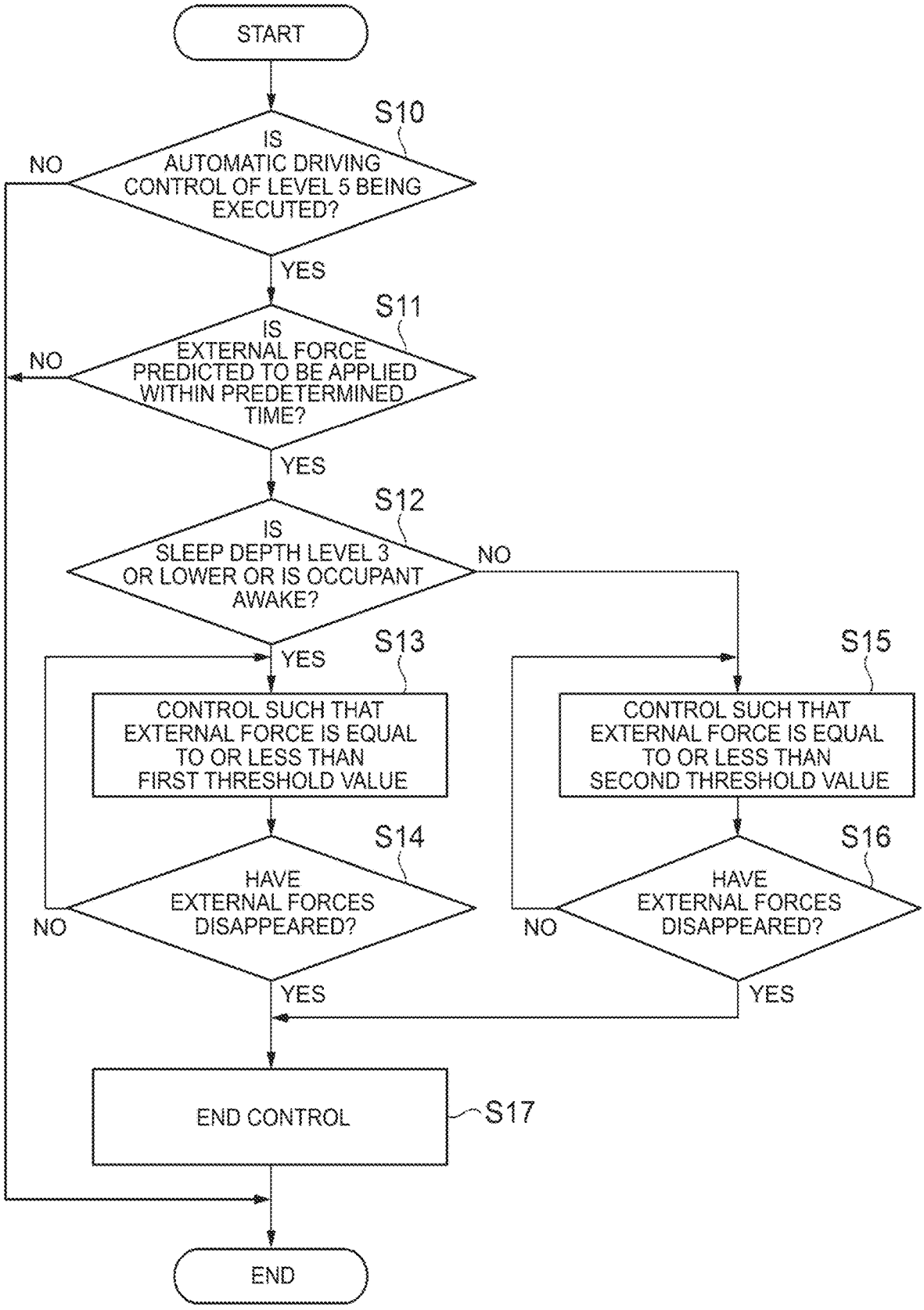

F3
θ1
UP
19C
FR
19C
DF
19B
19B
19
19A

FIG. 14


START
S10
IS AUTOMATIC DRIVING CONTROL OF LEVEL 5 BEING EXECUTED?
NO
YES
S11
IS EXTERNAL FORCE PREDICTED TO BE APPLIED WITHIN PREDETERMINED TIME?
NO
YES
S12
IS SLEEP DEPTH LEVEL 3 OR LOWER OR IS OCCUPANT AWAKE?
NO
YES
S13
CONTROL SUCH THAT EXTERNAL FORCE IS EQUAL TO OR LESS THAN FIRST THRESHOLD VALUE
S14
HAVE EXTERNAL FORCES DISAPPEARED?
NO
YES
S15
CONTROL SUCH THAT EXTERNAL FORCE IS EQUAL TO OR LESS THAN SECOND THRESHOLD VALUE
S16
HAVE EXTERNAL FORCES DISAPPEARED?
NO
YES
END CONTROL
S17
END

VEHICLE CONTROL DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2021-077989 filed on Apr. 30, 2021, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to a vehicle control device.

2. Description of Related Art

The following Japanese Unexamined Patent Application Publication No. 2019-038356 (JP 2019-038356 A) discloses an disclosure in which a state of an occupant of a vehicle is detected and an automatic driving mode of the vehicle is changed according to the state of the occupant.

SUMMARY

In JP 2019-038356 A, the automatic driving mode is changed without considering an external force to be predicted to be applied to the occupant of the vehicle in the future. Therefore, J P 2019-038356 A has room for improvement in suppressing a large external force from being applied to the occupant of the vehicle in the future due to behavior of the vehicle.

In consideration of the above fact, an object of the present disclosure is to obtain a vehicle control device capable of suppressing a large external force from being applied to an occupant due to behavior of a vehicle while a sleep depth of the occupant seated in a seat is considered.

A vehicle control device according to claim **1** includes a sleep depth estimation unit that estimates a sleep depth of an occupant seated in a seat provided in a vehicle, an external force prediction unit that predicts an external force to be applied to the occupant within a predetermined time due to behavior of the vehicle, and a control unit that controls the vehicle such that a magnitude of the external force to be applied to at least one of a plurality of the occupants is equal to or less than a first threshold value when the sleep depth of the occupant estimated by the sleep depth estimation unit is equal to or lower than a predetermined reference depth, and that controls the vehicle such that the magnitude of the external force to be applied to each of all the occupants is equal to or less than a second threshold value larger than the first threshold value when the sleep depth of each of the occupants is greater than the reference depth.

In the vehicle control device according to claim **1**, the sleep depth estimation unit estimates the sleep depth of the occupant seated in the seat provided in the vehicle. Further, the external force prediction unit predicts the external force to be applied to the occupant within the predetermined time due to the behavior of the vehicle. Further, the control unit controls the vehicle such that the magnitude of the external force to be applied to the at least one of the occupants is equal to or less than the first threshold value when the sleep depth of the occupant estimated by the sleep depth estimation unit is equal to or lower than the predetermined reference depth or when the occupant is awake. Further, the control unit controls the vehicle such that the magnitude of the external force to be applied to each of all the occupants is equal to or less than the second threshold value larger than the first threshold value when the sleep depth of each of the occupants is greater than the reference depth.

As described above, the control unit of the vehicle control device according to claim **1** does not control the vehicle based on the magnitude of the external force actually applied to the occupant. That is, the control unit controls the vehicle such that the external force to be applied to the occupant is equal to or less than a predetermined threshold value while considering the external force predicted to be applied to the occupant within the predetermined time. Therefore, the vehicle control device according to claim **1** can suppress the large external force from being applied to the occupant due to the behavior of the vehicle.

Further, the control unit of the vehicle control device according to claim **1** controls the vehicle such that the magnitude of the external force to be applied to the at least one of the occupants is equal to or less than the first threshold value when the sleep depth of the occupant is equal to or lower than the reference depth or when the occupant is awake. Further, the control unit controls the vehicle such that the magnitude of the external force to be applied to each of all the occupants is equal to or less than the second threshold value larger than the first threshold value when the sleep depth of each of the occupants is greater than the reference depth. That is, the control unit controls the vehicle while considering the sleep depth of the occupant seated in the seat. Therefore, a vehicle speed to be allowed when the sleep depth of each of all the occupants is greater than the reference depth is higher than a vehicle speed to be allowed when the sleep depth is equal to or lower than the reference depth. Accordingly, when the sleep depth of each of all the occupants is greater than the reference depth, the vehicle can travel at a higher vehicle speed than when the sleep depth is equal to or lower than the reference depth.

As a result, the vehicle control device according to claim **1** can suppress the large external force due to the behavior of the vehicle from being applied to the occupant while considering the sleep depth of the occupant seated in the seat.

With the vehicle control device according to claim **2**, in the vehicle control device according to claim **1**, in a case where the sleep depth of the at least one of the occupants is equal to or lower than the reference depth or the occupant is awake, the control unit moves the seat in the same direction as the external force when the external force is applied to the occupant.

In the vehicle control device according to claim **2**, when the sleep depth of the at least one of the occupants is equal to or lower than the reference depth or when the occupant is awake, the control unit moves the seat in the same direction as a direction of the external force to suppress the large external force from being applied to the occupant. Further, the control unit executes such control only when the sleep depth is equal to or lower than the reference depth or when the occupant is awake. Therefore, energy consumption required for controlling the vehicle can be suppressed as compared with a case where the control is executed even when the sleep depth is greater than the reference depth.

With the vehicle control device according to claim **3**, in the vehicle control device according to claim **1** or **2**, the external force prediction unit predicts the external force based on at least one of radius of curvature of a road, an inclination angle of the road, and an uneven portion of a road surface of the road, the radius of curvature and the inclination angle being obtained from at least one of image data

obtained by capturing an image of the road on which the vehicle travels and map information including information on the road.

In the vehicle control device according to claim **3**, the external force prediction unit predicts the external force to be applied to the occupant within the predetermined time based on at least one of the radius of curvature of the road and the inclination angle of the road, the radius of curvature and the inclination angle being obtained from at least one of the image data obtained by capturing an image of the road on which the vehicle travels and the map information including the information on the road. Therefore, the external force prediction unit can predict a centrifugal force (external force) to be applied to the occupant within the predetermined time based on, for example, the radius of curvature of the road. Further, the external force prediction unit can predict the external force in an extension direction (vehicle front-rear direction) of the road, the external force being applied to the occupant within the predetermined time based on the inclination angle of the road.

With the vehicle control device according to claim **4**, in the vehicle control device according to claim **3**, the external force prediction unit predicts a centrifugal force to be applied to the occupant as the external force based on the radius of curvature, and the control unit moves the seat in the same direction as the centrifugal force along a width direction of the vehicle.

In the vehicle control device according to claim **4**, when the external force prediction unit predicts that the centrifugal force due to the radius of curvature of the road is applied to the occupant in the vehicle as the external force within the predetermined time, the control unit moves the seat in the same direction as the centrifugal force along the width direction of the vehicle. At this time, an inertial force in a direction opposite to a direction of the centrifugal force is generated in the seat, and a part of the centrifugal force is cancelled out by this inertial force. Therefore, when the vehicle travels on a curved road, the large centrifugal force (external force in the width direction of the vehicle) is suppressed from being applied to the occupant.

With the vehicle control device according to claim **5**, in the vehicle control device according to claim **3** or **4**, the seat includes a seat cushion on which a waist of the occupant is placed, a seat back that is rotatably supported by the seat cushion and that comes into contact with a back of the occupant, and a reclining mechanism for adjusting an angle of the seat back with respect to the seat cushion, and the external force prediction unit predicts the external force to be applied to the occupant due to the inclination angle of the road, and the control unit controls the reclining mechanism to rotate the seat back in the same direction as a direction of the external force due to the inclination angle.

In the vehicle control device according to claim **5**, when the external force prediction unit predicts that the external force due to the inclination angle of the road is applied to the occupant in the vehicle within the predetermined time, the control unit rotates the seat back in the same direction as the direction of the external force due to the inclination angle of the road. At this time, an inertial force in a direction opposite to the direction of the external force is generated in the seat, and a part of the external force is cancelled out by this inertial force. Therefore, when the vehicle travels on an inclined road, the large external force due to the inclination angle is suppressed from being applied to the occupant.

With the vehicle control device according to claim **6**, in the vehicle control device according to any one of claims **1** to **5**, the seat includes a seat cushion on which a waist of the occupant is placed, a seat back that is rotatably supported by the seat cushion and that comes into contact with a back of the occupant, and a reclining mechanism for adjusting an angle of the seat back with respect to the seat cushion, and when the sleep depth is greater than the reference depth, the control unit controls the reclining mechanism to increase the angle between the seat back and the seat cushion as compared with a case where the sleep depth is equal to or lower than the reference depth or the occupant is awake.

In the vehicle control device according to claim **6**, when the sleep depth is greater than the reference depth, the control unit controls the reclining mechanism to increase the angle between the seat back and the seat cushion as compared with a case where the sleep depth is equal to or lower than the reference depth or the occupant is awake. With this configuration, the occupant in a state of deep sleeping can easily maintain the state of deep sleeping.

As described above, the vehicle control device according to the present disclosure has excellent effects in that the large external force due to the behavior or the vehicle can be suppressed from being applied to the occupant while the sleep depth of the occupant seated in the seat is considered.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

FIG. **1** is a schematic plan view showing a vehicle of which a ceiling portion is omitted and that includes a vehicle control device according to an embodiment;

FIG. **2** is a schematic side view of a front seat and an occupant of the vehicle shown in FIG. **1**;

FIG. **3** is a schematic cross-sectional view of a seat headrest;

FIG. **4** is a schematic side view of a rear seat and an occupant of the vehicle shown in FIG. **1**;

FIG. **5** is a schematic block diagram of an electronic control unit (ECU) of the vehicle shown in FIG. **1**;

FIG. **6** is a functional block diagram of the ECU shown in FIG. **5**;

FIG. **7** is a side view showing a state in which the vehicle travels on a road including an uneven portion;

FIG. **8** is a plan view showing a state in which the vehicle travels on a road including a curved portion;

FIG. **9** is a side view showing a state in which the vehicle moves from a horizontal portion of a road to an inclined portion of the road;

FIG. **10** is a schematic side view showing the seat headrest and a head of the occupant;

FIG. **11** is a schematic side view showing a seat headrest and a head of an occupant according to a comparative example;

FIG. **12** is a schematic side view of a seat raised and lowered by a lifter mechanism;

FIG. **13** is a schematic side view of the seat in which a seat back is rotated by a reclining mechanism; and

FIG. **14** is a flowchart showing a process performed by an ECU.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, a vehicle control device **10** according to an embodiment of the present disclosure will be described with reference to the accompanying drawings. An arrow FR indicates a vehicle front direction, an arrow UP indicates a

vehicle upward direction, and an arrow LH indicates a left side of a vehicle right-left direction (vehicle width direction). Each of the arrows is appropriately shown in each drawing. Hereinafter, when description is simply made using front-rear, right-left, and up-down directions, the front-rear direction of the vehicle front-rear direction, the right-left direction of the vehicle right-left direction (vehicle width direction), and the up-down direction of the vehicle up-down direction are shown.

As shown in FIG. **1**, a steering wheel **14**D is provided on an instrument panel **14**C of a vehicle body **14** of a vehicle **12** on which the vehicle control device **10** is mounted. Further, a front seat **16** is provided in a vehicle cabin **14**A. As shown in FIG. **2**, an occupant P**1** is seated in the front seat **16**. The front seat **16** includes a seat **19** and a slide rail device **20**.

As shown in FIG. **2**, a floor **14**B of the vehicle cabin **14**A is provided with the slide rail device **20** that supports the seat **19** of the front seat **16** such that the seat **19** can be slid in the right-left direction. The slide rail device **20** includes a pair of front and rear lower rails **21** fixed to the floor **14**B and extending in the right-left direction, and a pair of front and rear upper rails **22**. Each of the upper rails **22** is supported by each of the lower rails **21** such that the upper rails **22** are slidable in the right-left direction. The slide rail device **20** includes a first actuator **24** composed of an electric motor and a power transmission mechanism (not shown). When the first actuator **24** generates a driving force while rotating in a normal direction, this driving force is transmitted from the power transmission mechanism to the upper rails **22**, and causes the upper rails **22** to slide to the left with respect to the lower rails **21**. When the first actuator **24** generates a driving force while rotating in a reverse direction, this driving force is transmitted from the power transmission mechanism to the upper rails **22**, and causes the upper rails **22** to slide to the right with respect to the lower rails **21**.

The seat **19** is supported by the front and rear upper rails **22**. The seat **19** includes a seat cushion **19**A, a seat back **19**B and a headrest **19**C. The seat cushion **19**A is fixed to the upper ends of the front and rear upper rails **22**. The rear end of the seat cushion **19**A and the lower end of the seat back **19**B are rotatably connected via a reclining mechanism **26**. The reclining mechanism **26** is provided with a second actuator **28**. When the second actuator **28** generates a driving force while rotating in the normal direction, the reclining mechanism **26** rotates by this driving force, and the seat back **19**B rotates relative to the seat cushion **19**A forward. When the second actuator **28** generates a driving force while rotating in the reverse direction, the reclining mechanism **26** rotates by this driving force, and the seat back **19**B rotates relative to the seat cushion **19**A rearward.

As shown in FIGS. **2** and **3**, the headrest **19**C includes a cushion portion **19C1** and a pair of right and left stays **19C2** whose upper ends are fixed to the cushion portion **19C1**. The right and left stays **19C2** are slidably supported on the upper end of the seat back **19**B in the up-down direction.

The cushion portion **19C1** includes a base portion **19C3** serving as a rear portion thereof and a pair of side portions **19C4**. Each of the side portions **19C4** extends forward from each of right and left ends of the base portion **19C3**. That is, the planar shape of the cushion portion **19C1** is a U-shape. The outer shape of the cushion portion **19C1** is composed of an outer skin material **19C5** having flexibility. In the internal space of the outer skin material **19C5**, a bag body **19C6** having a U-shape in a plan view, a plurality of springs **19C7**, and a cushion material (not shown) are provided. The bag body **19C6** is composed of a flexible material. The inside of the bag body **19C6** is filled with a liquid (not shown). One end of each spring **19C7** is supported by the bag body **19C6**, and the other end of each spring **19C7** is supported by the inner peripheral surface of the outer skin material **19C5**.

As shown in FIG. **1**, when the occupant P**1** is seated in the front seat **16** (seat **19**), a waist P**1***a* of the occupant P**1** is supported by the seat cushion **19**A, a back P**1***b* of the occupant P**1** is supported by the seat back **19**B, and a head P**1***c* of the occupant P**1** is supported by the cushion portion **19C1**. Further, as shown in FIG. **3**, the rear portion and both side portions of the head P**1***c* are surrounded by the cushion portion **19C1**. For example, as shown in FIG. **3**, the rear portion of the head P**1***c* is supported by the base portion **19C3** and both side portions of the head P**1***c* are supported by the side portions **19C4**.

As shown in FIGS. **1** and **4**, the floor **14**B is provided with a pair of right and left rear seats **30** located rearward of the front seat **16**. Each rear seat **30** includes a seat **19** and a lifter mechanism **32**.

The lifter mechanism **32** provided on the floor **14**B includes a third actuator **34** composed of an electric motor. In FIG. **4**, the lifter mechanism **32** is schematically shown. The lifter mechanism **32** has a configuration disclosed in, for example, Japanese Unexamined Patent Application Publication No. 2012-62020 (JP 2012-62020 A). The seat cushion **19**A of the seat **19** is supported on the upper end of the lifter mechanism **32**. When the third actuator **34** generates a driving force while rotating in the normal direction, the driving force causes the lifter mechanism **32** to extend in the up-down direction. When the third actuator **34** generates a driving force while rotating in the reverse direction, the driving force causes the lifter mechanism **32** to shorten in the up-down direction. When the lifter mechanism **32** extends and shortens in the up-down direction, the angle of the seat cushion **19**A in the side view with respect to the horizontal direction (front-rear direction) changes.

An occupant P**2** is seated in the rear seat **30**. When the occupant P**2** is seated in the rear seat **30** (seat **19**), a waist P**2***a* of the occupant P**2** is supported by the seat cushion **19**A, a back P**2***b* of the occupant P**2** is supported by the seat back **19**B, and a head P**2***c* of the occupant P**2** is supported by the cushion portion **19C1**. Further, the rear portion and both side portions of the head P**2***c* are surrounded by the cushion portion **19C1**. For example, as shown in FIG. **3**, the rear portion of the head P**2***c* is supported by the base portion **19C3** and the both side portions of the head P**2***c* are supported by the side portions **19C4**.

Although not shown, the vehicle **12** includes three seatbelt devices each corresponding to the front seat **16** and the rear seats **30**. The occupant P**1** seated in the front seat **16** and the occupant P**2** seated in each of the rear seat **30** wear corresponding seatbelt devices.

As shown in FIG. **1**, in the vicinity of four wheels **38** provided on the vehicle **12** (only two front wheels are shown in FIG. **1**), a wheel speed sensor **40** that detects the wheel speed of each wheel **38** (only two wheel speed sensors are shown in FIG. **1**) is provided. Further, the vehicle **12** is provided with four brake devices **42** (only two brake devices are shown in FIG. **1**) capable of applying a braking force to each wheel **38**. Further, an engine **46** is provided at the front of the vehicle **12**.

As shown in FIG. **2**, a camera **50** is provided on the rear surface of the front windshield **14**E provided on the vehicle body **14**. The camera **50** can take an image of a subject located in front of the front windshield **14**E.

Further, as shown in FIGS. **2** and **4**, a heart rate monitor **52** is provided inside the seat back **19**B of the seat **19** of each

of the front seat **16** and the rear seats **30**. The heart rate monitor **52** in the front seat **16** measures the heart rate of the occupant P**1** seated in the front seat **16**. The heart rate monitor **52** in the rear seat **30** measures the heart rate of the occupant P**2** seated in the rear seat **30**.

Further, as shown in FIG. **1**, the vehicle **12** is provided with a Global Positioning System (GPS) receiver **54**. The GPS receiver **54** acquires position information (latitude, longitude, etc.) of a point where the vehicle **12** is traveling based on a GPS signal transmitted from an artificial satellite at a predetermined cycle.

Further, the instrument panel **14**C is provided with an automatic driving switch **56**.

As shown in FIG. **1**, the vehicle **12** is provided with an electronic control unit (ECU) **60**. The ECU **60** is electrically connected to the first actuator **24**, the second actuator **28**, the third actuator **34**, the wheel speed sensor **40**, the brake device **42**, the engine **46**, the camera **50**, the heart rate monitor **52**, the GPS receiver **54**, and the automatic driving switch **56**. The ECU **60** shown in FIG. **5** is configured to include a central processing unit (CPU: processor) **60**A, a read-only memory (ROM) **60**B, a random access memory (RAM) **60**C, a storage **60**D, a communication interface (I/F) **60**E, and an input-output I/F **60**F. The CPU **60**A, the ROM **60**B, the RAM **60**C, the storage **60**D, the communication I/F **60**E, and the input-output I/F **60**F are connected so as to be able to communicate with each other via a bus **60**Z. The ECU **60** can acquire information of the date and time from a timer (not shown).

The CPU **60**A is a central processing unit that executes various programs and that controls various units. That is, the CPU **60**A reads the program from the ROM **60**B or the storage **60**D and executes the program using the RAM **60**C as a work area. The CPU **60**A controls each configuration and performs various arithmetic processes in accordance with the program recorded in the ROM **60**B or the storage **60**D.

The ROM **60**B stores various programs and various data. The RAM **60**C temporarily stores a program or data as a work area. The storage **60**D is composed of a storage device such as a hard disk drive (HDD) or a solid state drive (SSD), and stores various programs and various data. The communication I/F **60**E is an interface for the ECU **60** to communicate with other devices. The input-output I/F **60**F is an interface for communicating with various devices.

The vehicle **12** is equipped with a navigation system. Map data, which is part of the navigation system, is recorded in the storage **60**D of the ECU **60**. The GPS receiver **54** is also a part of the navigation system. The map data received by the vehicle **12** from the Web server using wireless communication via the Internet may be used as part of the navigation system.

As shown in FIG. **6**, the ECU **60** includes a sleep depth estimation unit **601**, an external force prediction unit **602**, and an automatic driving control unit (control unit) **603** as functional configurations. The sleep depth estimation unit **601**, the external force prediction unit **602**, and the automatic driving control unit **603** are realized by the CPU **60**A reading and executing the program stored in the ROM **60**B or the storage **60**D.

When the ECU **60** acquires data on the heart rates of the occupants P**1** and P**2** acquired by the heart rate monitors **52**, the sleep depth estimation unit **601** estimates (detects) the sleep depths of the occupants P**1** and P**2** based on the data. The sleep depth estimation unit **601** according to the present embodiment estimates the sleep depth in five levels. That is, the sleep depth estimated by the sleep depth estimation unit **601** includes the sleep depths of levels 1 to 5. The sleep depth of level 1 is the depth corresponding to rapid eye movement (REM) sleep. Each of the sleep depths of levels 2 to 5 is the depth corresponding to non-rapid eye movement (Non-REM) sleep. Levels 2 and 3 correspond to the Non-REM sleep in stages 1 and 2, respectively. Levels 4 and 5 correspond to the Non-REM sleep (slow wave sleep) in stage 3 and 4, respectively.

The external force prediction unit **602** calculates (predicts) the magnitude and the direction of the external force to be applied to the occupants P**1** and P**2** within a predetermined time from the current time based on information acquired by the ECU **60** from the navigation system, the wheel speed sensor **40**, and the camera **50**. This predetermined time is, for example, 10 seconds. However, this predetermined time may be a time having a length different from 10 seconds.

For example, as shown in FIG. **7**, a case is assumed in which an uneven portion **72** existing on a road surface **71** of a road **70** in which the vehicle **12** is traveling along a traveling direction A is included in image data transmitted from the camera **50** to the ECU **60**. In this case, the external force prediction unit **602** predicts an external force F**1** in the up-down direction to be applied to the vehicle **12** from the road surface **71** when the wheels **38** of the vehicle **12** that maintains the vehicle speed at the current time gets over the uneven portion **72** within the predetermined time from the current time, based on information including the vehicle speed at the current time calculated based on information related to the wheel speed transmitted from the wheel speed sensor **40**, the distance from the vehicle **12** to the uneven portion **72** calculated based on the image data, and the magnitude (height) of the uneven portion **72**. That is, the magnitude and the direction of the external force F**1** that causes the vehicle **12** to vibrate in the up-down direction are predicted.

Further, as shown in FIG. **8**, a case is assumed in which a curved portion **76** that is a part of a road **75** in which the vehicle **12** is traveling straight along a traveling direction B is included in the image data transmitted from the camera **50** to the ECU **60**. In this case, the external force prediction unit **602** predicts, based on information including the vehicle speed at the current time and the radius of curvature of the curved portion **76**, the magnitude and the direction of a centrifugal force (external force) F**2** to be applied to the vehicle **12** (occupants P**1** and P**2**) when the vehicle **12** that maintains the vehicle speed at the current time travels on the curved portion **76** within the predetermined time from the current time. The radius of curvature of the curved portion **76** can be calculated by the external force prediction unit **602** based on the image data. The external force prediction unit **602** can recognize the curved portion **76** on the road **75** and the radius of curvature of the curved portion **76** based on information acquired by the ECU **60** from the map information of the navigation system. That is, the external force prediction unit **602** can recognize the curved portion **76** on the road **75** and the radius of curvature of the curved portion **76** based on information from one of the camera **50** and the navigation system.

Further, as shown in FIG. **9**, a case is assumed in which an inclined portion (slope) **82** that is a part of a road **80** is included in the image data captured by the camera **50** and transmitted to the ECU **60** when the vehicle **12** is traveling on a horizontal portion **81** of the road **80** along a traveling direction C. In this case, the external force prediction unit **602** predicts the magnitude and the direction of an external force F**3** to be applied to the vehicle **12** (occupants P**1** and

P2) when the vehicle **12** that maintains the vehicle speed at the current time moves from the horizontal portion **81** to the inclined portion **82** within the predetermined time from the current time based on information including the vehicle speed at the current time, an inclination angle (gradient) **01** of the inclined portion **82**, and an inclination direction of the inclined portion **82**. As shown by the arrow in FIG. **9**, the external force F**3** is a force in a rotational direction along an extension direction (vehicle front-rear direction) of the road **80**. The inclination angle θ1 and the inclination direction of the inclined portion **82** can be estimated (calculated) by the external force prediction unit **602** from the image data. The external force prediction unit **602** can recognize, based on the information acquired by the ECU **60** from the map information of the navigation system, the inclined portion **82** on the road **80** in which the vehicle **12** is traveling, and the inclination angle θ1 and the inclination direction of the inclined portion **82**. That is, the external force prediction unit **602** can recognize the inclined portion **82** on the road **80** and the inclination angle θ1 and the inclination direction of the inclined portion **82** based on the information from one of the camera **50** and the navigation system.

The automatic driving control unit **603** functions when the automatic driving switch **56** located at the OFF position moves to the ON position. The automatic driving control unit **603** executes automatic driving control (driving support control) of the vehicle **12** by operating each device of the vehicle **12** including the brake device **42**, the engine **46**, and the steering device (not shown). The term "automatic driving" used in the present specification includes 1 to 5 levels of automatic driving defined by Society of Automotive Engineers (SAE).

Operation and Effects

Next, the operation and effects of the present embodiment will be described.

The ECU **60** of the vehicle control device **10** repeatedly executes the process of the flowchart of FIG. **14**.

First, in step S**10**, the automatic driving control unit **603** of the ECU **60** determines whether the automatic driving control of level 5 is being executed. That is, the automatic driving control unit **603** determines whether the vehicle **12** is executing so-called fully automatic driving.

The ECU **60** that has determined Yes in step S**10** proceeds to step S**11**. In step S**11**, the external force prediction unit **602** of the ECU **60** determines whether the above external force is predicted to be applied to the vehicle **12** within the predetermined time from the current time. That is, the external force prediction unit **602** determines whether at least one of the external force F**1**, the external force F**2**, and the external force F**3** is applied to the vehicle **12** within the predetermined time from the current time, for example.

The ECU **60** that has determined Yes in step S**11** proceeds to step S**12**. In step S**12**, the sleep depth estimation unit **601** of the ECU **60** estimates the sleep depths of the occupants P**1** and P**2** based on the data related to the heart rates of the occupants P**1** and P**2** acquired from the heart rate monitor **52**. Further, the sleep depth estimation unit **601** determines whether the sleep depth of at least one of the occupant P**1** and the occupant P**2** is equal to or lower than a reference depth or at least one of the occupant P**1** and the occupant P**2** is awake. The reference depth according to the present embodiment is a sleep depth of level 3. Therefore, when the sleep depth of at least one of the occupant P**1** and the occupant P**2** is one of levels 1 to 3, or at least one of the occupant P**1** and the occupant P**2** is awake, the sleep depth estimation unit **601** determines Yes in step S**12**. On the other hand, when the sleep depths of all the occupants are level 4 or level 5, the sleep depth estimation unit **601** determines No in step S**12**.

The ECU **60** that has determined Yes in step S**12** proceeds to step S**13**. For example, when the sleep depths of the occupants P**1** and P**2** are level 3 or lower, the ECU **60** proceeds to step S**13**.

For example, when the vehicle **12** passes through the uneven portion **72** of FIG. **7**, the automatic driving control unit **603** of the ECU **60** that has proceeded to step S**13** controls the brake device **42** such that the magnitude of the external force F**1** to be applied to the vehicle **12** is equal to or less than a predetermined first threshold value. That is, the automatic driving control unit **603** applies the braking force from the brake device **42** to each wheel **38** to reduce the vehicle speed of the vehicle **12**. Here, the first threshold value is a value obtained by multiplying a first coefficient that is "zero" or more and smaller than "one" by the magnitude of the external force F**1** when the vehicle **12** passes through the uneven portion **72** at the vehicle speed of the current time. The first coefficient is recorded in the ROM **60**B or the storage **60**D.

The magnitude of the external force F**1** in the up-down direction to be applied from the uneven portion **72** to the vehicle **12** (occupants P**1** and P**2**) when the vehicle **12** passes through the uneven portion **72** increases as a vehicle speed when the vehicle **12** passes through the uneven portion **72** increases. Therefore, when the vehicle **12** passes through the uneven portion **72** at a speed equal to or lower than a predetermined vehicle speed, the external force F**1** to be applied to the vehicle **12** is equal to or less than the first threshold value. Therefore, when the vehicle **12** passes through the uneven portion **72**, there is little possibility that the occupants P**1** and P**2** in states of light sleeping will wake up. Further, a possibility that transition from the wake-up states of the occupants P**1** and P**2** to the sleeping states thereof is hindered by the vehicle **12** passing through the uneven portion **72** is reduced.

Further, when the ECU **60** performs the process of step S**13**, as shown in FIG. **10**, the automatic driving control unit **603** may control the second actuator **28** (reclining mechanism **26**) to reduce the angle θ2 between the up-down direction and an extension direction D of the seat back **19**B of the seat **19** of each of the front seat **16** and the rear seats **30**. As shown in FIG. **10**, the external force F**1** to be applied to the vehicle **12** is transmitted as a force F**1***p* from the base portion **19**C**3** of the seat **19** to the heads P**1***c* and P**2***c* of the occupants P**1** and P**2**. This force F**1***p* is a value obtained by multiplying the external force F**1** by sin θ2. Therefore, the smaller the value of the angle θ2 becomes, the smaller the value of the force F**1***p* becomes. The external force to be applied to the heads P**1***c* and P**2***c* of the occupants P**1** and P**2** has a greater influence on the sleeping states of the occupants P**1** and P**2** than the external force to be applied to the parts other than the heads P**1***c* and P**2***c* of the occupants P**1** and P**2**. Therefore, by reducing the angle θ2 between the up-down direction and the extension direction D of the seat back **19**B of the seat **19** of each of the front seat **16** and the rear seats **30**, when the vehicle **12** passes through the uneven portion **72**, the possibility that the occupants P**1** and P**2** in states of light sleeping will wake up can be reduced, and the possibility that the transition from the wake-up states of the occupants P**1** and P**2** to the sleeping states thereof is hindered can be reduced.

FIG. **11** is a comparative example of FIG. **10**. In this comparative example, when the ECU **60** performs the pro-

cess of step S13, as shown in FIG. 11, the automatic driving control unit 603 controls the second actuator 28 (reclining mechanism 26) to increase the angle θ2. The angle θ2 in this case is about 90°. In this case, as shown in FIG. 11, the external force F1 to be applied to the vehicle 12 is transmitted to the heads P1*c* and P2*c* of the occupants P1 and P2 as a force having almost the same magnitude as that of the external force F1. Therefore, in this case, when the vehicle 12 passes through the uneven portion 72, the possibility that the occupants P1 and P2 in the states of light sleeping will wake up is higher than in the case of FIG. 10, and the possibility that the transition from the wake-up states of the occupants P1 and P2 to the sleeping states thereof is hindered is higher than in the case of FIG. 10.

Further, for example, when the vehicle 12 travels on the road 75 of FIG. 8, the automatic driving control unit 603 of the ECU 60 that has proceeded to step S13 controls the brake device 42 such that the external force (centrifugal force) F2 to be applied to the occupants P1 and P2 when the vehicle 12 travels on the curved portion 76 is equal to or less than the first threshold value. That is, the automatic driving control unit 603 applies the braking force from the brake device 42 to each wheel 38 to reduce the vehicle speed of the vehicle 12. The first threshold value in this case is a value obtained by multiplying the first coefficient by the magnitude of the external force F2 when the vehicle 12 passes through the curved portion 76 at the vehicle speed of the current time. The magnitude of the external force F2 when the vehicle 12 travels on the curved portion 76 is proportional to the square of the vehicle speed. Therefore, by reducing the vehicle speed when the vehicle 12 travels on the curved portion 76, the magnitude of the external force F2 to be applied to the occupants P1 and P2 when the vehicle 12 travels on the curved portion 76 is equal to or less than the first threshold value. Therefore, when the vehicle 12 passes through the curved portion 76, there is little possibility that the occupants P1 and P2 in states of light sleeping will wake up. Further, the possibility that the transition from the wake-up states of the occupants P1 and P2 to the sleeping states thereof is hindered by the vehicle 12 passing through the curved portion 76 is reduced.

Further, in step S13, the automatic driving control unit 603 controls the first actuator 24. More specifically, when the vehicle 12 travels on the curved portion 76, the first actuator 24 controlled by the automatic driving control unit 603 causes the upper rails 22 and the seat 19 of the front seat 16 to slide to the right side with respect to the lower rails 21 (width direction of the vehicle 12). Since a leftward inertial force IF (see FIG. 8) to be generated in the seat 19 by the sliding of the seat 19 to the right side is a force in a direction opposite to the direction of the external force F2, this inertial force IF is cancelled out by a part of the external force F2. Therefore, when the seat 19 is moved to the right side, the external force F2 to be applied to the occupant P1 becomes smaller.

Further, for example, when the vehicle 12 travels on the road 80 of FIG. 9, the automatic driving control unit 603 of the ECU 60 that has proceeded to step S13 controls the brake device 42 such that the external force F3 to be applied to the occupants P1 and P2 is equal to or less than the first threshold value. That is, the automatic driving control unit 603 applies the braking force from the brake device 42 to each wheel 38 to reduce the vehicle speed of the vehicle 12. The first threshold value in this case is a value obtained by multiplying the first coefficient by the magnitude of the external force F3 when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82 at the vehicle speed of the current time. The magnitude of the external force F3 when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82 increases as the vehicle speed increases. Therefore, by reducing the vehicle speed when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82, the magnitude of the external force F3 to be applied to the occupants P1 and P2 when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82 is equal to or less than the first threshold value. Therefore, when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82, there is little possibility that the occupants P1 and P2 in states of light sleeping will wake up. Further, the possibility that the transition from the wake-up states of the occupants P1 and P2 to the sleeping states thereof is hindered by the vehicle 12 moving from the horizontal portion 81 to the inclined portion 82 is reduced.

Further, in step S13, the automatic driving control unit 603 may control the third actuator 34. More specifically, when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82, the third actuator 34 controlled by the automatic driving control unit 603 may drive the lifter mechanism 32 of the rear seat 30 to rotate the entire seat 19 rearward by the inclination angle θ1 along the same direction as the external force F3 as shown in FIG. 12. The seat 19 shown by the solid line in FIG. 12 shows the seat 19 of the vehicle 12 that has moved to the inclined portion 82 without operating the third actuator 34. The seat 19 shown by the virtual line in FIG. 12 shows the seat 19 of the vehicle 12 that has moved to the inclined portion 82 while operating the third actuator 34. An inertial force DF to be generated in the seat 19 when the entire seat 19 is rotated in the same direction as the external force F3 by the third actuator 34 as described above is a force in a direction opposite to the direction of the external force F3. Therefore, the inertial force DF to be generated in the seat 19 when the entire seat 19 is rotated in the same direction as the external force F3 is cancelled out by a part of the external force F3. As a result, when the entire seat 19 is rotated in the same direction as the external force F3, the external force F3 to be applied to the occupant P2 becomes smaller.

The automatic driving control unit 603 may control the second actuator 28 instead of the third actuator 34. More specifically, when the vehicle 12 moves from the horizontal portion 81 to the inclined portion 82, the second actuator 28 controlled by the automatic driving control unit 603 may drive the reclining mechanism 26 of the rear seat 30 to rotate the seat back 19B rearward by the inclination angle θ1 along the same direction as the external force F3 as shown in FIG. 13. The seat back 19B shown by the solid line in FIG. 13 shows the seat back 19B of the vehicle 12 that has moved to the inclined portion 82 without operating the reclining mechanism 26. The seat back 19B shown by the virtual line in FIG. 13 shows the seat back 19B of the vehicle 12 that has moved to the inclined portion 82 while operating the reclining mechanism 26. The inertial force DF to be generated in the seat back 19B (occupant P2) when the seat back 19B is rotated in the same direction as the external force F3 by the reclining mechanism 26 as described above is cancelled out by a part of the external force F3. As a result, when the seat back 19B is rotated in the same direction as the external force F3, the external force F3 to be applied to the occupant P2 becomes smaller.

As shown by the virtual line in FIG. 9, when the road 80 includes an inclined portion 83 whose inclination direction is opposite to that of the inclined portion 82, in step S13, the automatic driving control unit 603 drives the lifter mecha-

nism **32** and reclining mechanism **26** to rotate the seat back **19**B in a direction opposite to the direction described above.

The automatic driving control unit **603** of the ECU **60** that has ended the process of step S**13** proceeds to step S**14** and determines whether the external forces F**1**, F**2**, and F**3** have disappeared. That is, the automatic driving control unit **603** determines whether the vehicle **12** has passed through the uneven portion **72** or the curved portion **76**, or the vehicle **12** that has moved to the inclined portion **82** has traveled on the inclined portion **82** by a predetermined distance, based on the position information obtained from the navigation system or the image data received from the camera **50**.

The ECU **60** that has determined Yes in step S**14** proceeds to step S**17**, and ends the control executed by the automatic driving control unit **603** in step S**13**. That is, the automatic driving control unit **603** controls the engine **46** (at least one of the opening degree of a throttle valve and the injection amount of fuel) to return the vehicle speed of the vehicle **12** to the vehicle speed before the process of step S**13** is executed. Further, the automatic driving control unit **603** returns the upper rails **22** and the seat **19** (seat back **19**B) to the positions before the process of step S**13** is executed.

On the other hand, when the determination result is No in step S**14**, the ECU **60** returns to step S**13**. That is, the automatic driving control unit **603** continues the control executed in step S**13**.

On the other hand, when the determination result is No in step S**12**, the ECU **60** proceeds to step S**15**. That is, when the sleep depths of all the occupants P**1** and P**2** are level 4 or level 5, the ECU **60** proceeds to step S**15**.

The process performed by the ECU **60** in step S**15** is similar to the process performed by the ECU **60** in step S**13**. However, the automatic driving control unit **603** of the ECU **60** that has proceeded to step S**15** controls the brake device **42** such that the magnitude of the external force F**1** to be applied to the vehicle **12** when the vehicle **12** passes through the uneven portion **72** of FIG. **7**, the magnitude of the external force F**2** when the vehicle **12** travels on the curved portion **76** of FIG. **8**, and the magnitude of the external force F**3** when the vehicle **12** moves from the horizontal portion **81** to the inclined portion **82** of FIG. **9** are equal to or less than a predetermined second threshold value. That is, the automatic driving control unit **603** applies the braking force from the brake device **42** to each wheel **38** to reduce the vehicle speed of the vehicle **12**. Here, the second threshold value of the external force F**1** is obtained by multiplying a second coefficient that is larger than "zero" and smaller than "one" by the magnitude of the external force F**1** when the vehicle **12** passes through the uneven portion **72** at the vehicle speed of the current time, and is larger than the first threshold value of the external force F**1**. Similarly, the second threshold value of the external force F**2** is a value obtained by multiplying the second coefficient by the magnitude of the external force F**2** when the vehicle **12** travels on the curved portion **76** at the vehicle speed of the current time, and is larger than the first threshold value of the external force F**2**. Similarly, the second threshold value of the external force F**3** is a value obtained by multiplying the second coefficient by the magnitude of the external force F**3** when the vehicle **12** moves from the horizontal portion **81** to the inclined portion **82** at the vehicle speed of the current time, and is larger than the first threshold value of the external force F**3**. That is, the second coefficient is larger than the first coefficient. The second coefficient is recorded in the ROM **60**B or the storage **60**D. Since the second coefficient is larger than the first coefficient, deceleration of the vehicle **12** in step S**15** is smaller than deceleration of the vehicle **12** in step S**13**.

The automatic driving control unit **603** of the ECU **60** that has ended the process of step S**15** proceeds to step S**16** and determines whether the external forces F**1**, F**2**, and F**3** have disappeared.

The ECU **60** that has determined Yes in step S**16** proceeds to step S**17**, and ends the control executed by the automatic driving control unit **603** in step S**15**.

On the other hand, when the determination result is No in step S**16**, the ECU **60** returns to step S**15**. That is, the automatic driving control unit **603** continues the control executed in step S**15**.

When the ECU **60** ends the process of step S**17**, or the determination result is NO in steps S**10** and S**11**, the ECU **60** temporarily ends the process of the flowchart of FIG. **14**.

In the vehicle control device **10** according to the present embodiment described above, the automatic driving control unit **603** of the ECU **60** controls the vehicle **12** such that the external forces F**1**, F**2**, and F**3** are equal to or less than the predetermined threshold value while considering the external forces F**1**, F**2**, and F**3** that are predicted to be applied to the occupants P**1** and P**2** within the predetermined time. That is, the vehicle control device **10** does not control the vehicle **12** based on the magnitudes of the external forces F**1**, F**2**, and F**3** that are actually generated. Therefore, the vehicle control device **10** can suppress the large external forces F**1**, F**2**, and F**3** from being applied to the occupants P**1** and P**2** due to the behavior of the vehicle **12**.

Further, when the sleep depth of at least one of the occupant P**1** and the occupant P**2** is equal to or lower than the reference depth or at least one of the occupant P**1** and the occupant P**2** is in the wake-up state, the automatic driving control unit **603** controls the vehicle **12** such that the magnitudes of the external forces F**1**, F**2** and F**3** to be applied to the occupants P**1** and P**2** are equal to or less than the first threshold value. On the other hand, when the sleep depths of all the occupants P**1** and P**2** are greater than the reference depth, the automatic driving control unit **603** controls the vehicle **12** such that the magnitudes of the external forces F**1**, F**2**, and F**3** to be applied to the occupants P**1** and P**2** are equal to or less than the second threshold value larger than the first threshold value. That is, the ECU **60** of the vehicle control device **10** controls the vehicle **12** while considering the sleep depths of the occupants P**1** and P**2**. Further, the second threshold value that is a threshold value to be adopted when the sleep depths of the occupants P**1** and P**2** are greater than the reference depth is larger than the first threshold value that is a threshold value to be adopted when the sleep depths of the occupants P**1** and P**2** are equal to or lower than the reference depth or the occupants P**1** and P**2** are in the wake-up states. That is, the vehicle speed to be allowed when the sleep depths of the occupants P**1** and P**2** are great is higher than the vehicle speed to be allowed when the sleep depths are low. Therefore, when the sleep depths of the occupants P**1** and P**2** are great, the vehicle **12** can travel at a higher vehicle speed than when the sleep depths are low.

Therefore, the vehicle control device **10** according to the present embodiment can suppress the large external forces F**1**, F**2**, and F**3** from being applied to the occupants P**1** and P**2** due to the behavior of the vehicle **12** while considering the sleep depths of the occupants P**1** and P**2** seated on the seat **19**.

Further, the headrest **19**C of each seat **19** includes the base portion **19**C**3** and the pair of side portions **19**C**4**. As shown

in FIG. **3**, the rear surface of each of the heads P1*c* and P2*c* is supported by the base portion **19**C**3** and the both side surfaces of each of the heads P1*c* and P2*c* are supported by the side portions **19**C**4**. Therefore, forces due to the external forces F**1**, F**2**, and F**3** are dispersed more widely to be transmitted from the headrest **19**C to the heads P1*c* and P2*c* than when the headrest **19**C does not include the side portions **19**C**4**. Therefore, when the forces due to the external forces F**1**, F**2**, and F**3** are applied to the heads P1*c* and P2*c*, an influence of the forces on the sleeping states of the occupants P**1** and P**2** can be reduced as compared with a case where the headrest **19**C does not include the side portions **19**C**4**.

Further, the headrest **19**C includes the bag body **19**C**6** filled with a liquid and the springs **19**C**7**. This bag body **19**C**6** functions as a damper. Further, when the forces due to the external forces F**1**, F**2**, and F**3** are applied from the headrest **19**C to the heads P1*c* and P2*c*, the springs **19**C**7** are elastically deformed. Therefore, when the forces due to the external forces F**1**, F**2**, and F**3** are applied to the heads P1*c* and P2*c*, an influence of the external forces F**1**, F**2**, and F**3** on the sleeping states of the occupants P**1** and P**2** can be reduced as compared with a case where the headrest **19**C does not include the bag body **19**C**6** and the springs **19**C**7**.

Further, in the vehicle control device **10**, when the sleep depth of the occupant P**1** is equal to or lower than the reference depth or when the occupant P**1** is in the wake-up state, the automatic driving control unit **603** of the ECU **60** uses the slide rail device **20** and the first actuator **24** to move the front seat **16** in the same direction as the external force F**2** and suppress the large external force F**2** from being applied to the occupant P**1**.

Further, when the external force prediction unit **602** predicts that the external force F**3** due to the inclination angle θ1 of the road **80** will be applied to the occupant P**2** in the vehicle **12** within the predetermined time from the current time, the vehicle control device **10** rotates the seat **19** (or seat back **19**B) in the same direction as a direction of the external force F**3** due to the inclination angle θ1. Therefore, when the vehicle **12** moves from the horizontal portion **81** of the road **80** to the inclined portion **82** of the road **80**, it is possible to suppress the large external force due to the inclination angle θ1 from be applied to the occupant P**2**.

Further, the automatic driving control unit **603** executes these controls for moving the seat **19** in the same direction as the external forces F**2** and F**3** only when the sleep depths of the occupants P**1** and P**2** are equal to or lower than the reference depth or the occupants P**1** and P**2** are in the wake-up states. Therefore, energy consumption required for controlling the vehicle **12** can be suppressed as compared with a case where these controls are executed even when the sleep depth is greater than the reference depth.

Although the vehicle control device **10** according to the embodiment has been described above, the design of the vehicle control device **10** can be appropriately changed without departing from the scope of the present disclosure.

For example, when the sleep depth is greater than the reference depth, the automatic driving control unit **603** may increase the angle between the seat cushion **19**A and the seat back **19**B as compared with a case where the sleep depth is equal to or lower than the reference depth, by controlling the reclining mechanism **26** (first actuator **24**) to rotate the seat back **19**B rearward. With this configuration, the occupants P**1** and P**2** in states of deep sleeping can easily maintain the states of deep sleeping.

Further, various types and magnitudes of an external force applied to a vehicle having the same specifications as the vehicle **12** (not shown) when the vehicle travels on various roads may be stored in an external server with which the vehicle **12** can communicate, together with position information indicating a location where the external force is generated and a vehicle speed when the external force is generated. In this case, when the vehicle **12** accesses the external server, the external force prediction unit **602** of the ECU **60** can determine whether the external force is applied to the vehicle **12** within a predetermined time from the current time. Further, the external force prediction unit **602** can recognize the maximum value of the vehicle speed for setting the magnitude of the external force predicted to be applied to the vehicle **12** within the predetermined time from the current time to a value equal to or less than a predetermined value (for example, the first threshold value and the second threshold value) more accurately than the above embodiment. Therefore, in the vehicle **12** according to the modification, the magnitude of the external force can be set to the value equal to or less than the predetermined value while the vehicle speed is increased as compared with the above embodiment.

The slide rail device **20** may be omitted from the front seat **16**. Further, the lifter mechanism **32** may be provided on the front seat **16**.

The lifter mechanism **32** may be omitted from the rear seat **30**. Further, the slide rail device **20** may be provided on the rear seat **30**.

The heart rate monitor **52** may be omitted from the seat **19**, and the occupants P**1** and P**2** may wear a wearable device capable of measuring the heart rates of the occupants P**1** and P**2** and wirelessly transmitting the acquired heart rate data to the ECU **60**.

Further, the heart rate monitor **52** may be omitted from the seat **19**, and the vehicle **12** may be provided with an in-vehicle camera capable of capturing the faces of the occupants P**1** and P**2**. Image data captured by the in-vehicle camera is sent to the ECU **60** and analyzed by the sleep depth estimation unit **601**. The sleep depth estimation unit **601** determines the sleep depth based on the states of the eyes, etc. of the occupants P**1** and P**2** included in the image data. For example, the sleep depth estimation unit **601** measures the degree to which the eyelids of the occupants P**1** and P**2** are open and the cycle of opening and closing the eyelids from the images of surrounding portions of the eyes of the occupants P**1** and P**2**. Further, the automatic driving control unit **603** estimates the sleep depths of the occupants P**1** and P**2** based on the measured degree to which the eyelids of the occupants P**1** and P**2** are open and the measured cycle of opening and closing the eyelids.

In step S**15**, similarly to step S**13**, the ECU **60** may control at least one of the first actuator **24**, the second actuator **28**, and the third actuator **34**.

When the automatic driving level is one of levels 1 to 4 or when the automatic driving switch **56** is in the OFF position, the ECU **60** may execute the process of the flowchart of FIG. **14** (excluding step S**10**).

The present disclosure may be applied to a vehicle in which automatic driving control cannot be performed.

When the external force prediction unit **602** predicts that the external forces F**1**, F**2**, and F**3** having magnitudes equal to or larger than the predetermined value will not be applied within a predetermined time from the current time, and the sleep depth estimation unit **601** determines that the sleep depths of all the occupants P**1** and P**2** are greater than the reference depth, as shown in FIG. **11**, the automatic driving control unit **603** may control the second actuator **28** (reclining mechanism **26**) to set the angle θ2 to about 90°. That is,

the angle θ2 may be increased as compared with a case where the sleep depth is equal to or lower than the reference depth. With this configuration, the occupant in a state of deep sleeping can easily maintain the state of deep sleeping.

Further, the seat **19** may include a device for adjusting the amount of liquid in the bag body **19**C**6** based on at least one of the sleep depth of the occupant and the magnitudes of the external forces F**1**, F**2**, and F**3**. This device adjusts the amount of liquid such that the bag body **19**C**6** exerts an appropriate damper effect according to the sleep depth of the occupant and the magnitudes of the external forces F**1**, F**2**, and F**3**. When the present disclosure is carried out according to the embodiment in the modification, an influence of the external forces F**1**, F**2** and F**3** on the sleeping states of the occupants P**1** and P**2** becomes smaller.

What is claimed is:

1. A vehicle control device comprising:

a processor configured to

estimate a sleep depth of each of a plurality of occupants seated in a seat provided in a vehicle;

predict an external force to be applied to at least one of the plurality of occupants within a predetermined time due to behavior of the vehicle; and

control the vehicle such that

a magnitude of the external force to be applied to the at least one of the plurality of the occupants is equal to or less than a first threshold value in response to (i) the estimated sleep depth of the at least one occupant being equal to or lower than a predetermined reference depth or (ii) the at least one occupant being awake, and

the magnitude of the external force to be applied to each of all of the plurality of occupants is equal to or less than a second threshold value larger than the first threshold value in response to the estimated sleep depth of each of all of the plurality of occupants being greater than the predetermined reference depth,

wherein the processor is further configured to, in response to predicting the external force to be applied to the at least one of the plurality of occupants within the predetermined time due to the behavior of the vehicle, estimate the sleep depth of each of the plurality of occupants seated in the seat provided in the vehicle.

2. The vehicle control device according to claim **1**, wherein

the processor is further configured to, in response to the estimated sleep depth of the at least one occupant being equal to or lower than the predetermined reference depth or the at least one occupant being awake, move the seat in a same direction as the external force when the external force is applied to the at least one occupant.

3. The vehicle control device according to claim **1**, wherein

the processor is further configured to predict the external force based on at least one of radius of curvature of a road, an inclination angle of the road, or an uneven portion of a road surface of the road, the radius of curvature and the inclination angle being obtained from at least one of image data obtained by capturing an image of the road on which the vehicle travels and map information including information on the road.

4. The vehicle control device according to claim **3**, wherein

the processor is further configured to

predict a centrifugal force to be applied to the at least one occupant as the external force based on the radius of curvature; and

move the seat in a same direction as the centrifugal force along a width direction of the vehicle.

5. The vehicle control device according to claim **3**, wherein

the seat includes

a seat cushion configured to support a waist of the occupant,

a seat back that is rotatably supported by the seat cushion and is configured to contact with a back of the occupant, and

a reclining mechanism for adjusting an angle of the seat back with respect to the seat cushion, and

the processor is further configured to

predict the external force to be applied to the at least one occupant due to the inclination angle of the road; and

control the reclining mechanism to rotate the seat back in a same direction as a direction of the external force due to the inclination angle.

6. The vehicle control device according to claim **1**, wherein

the seat includes

a seat cushion configured to support a waist of the occupant,

a seat back that is rotatably supported by the seat cushion and is configured to contact with a back of the occupant, and

a reclining mechanism for adjusting an angle of the seat back with respect to the seat cushion, and

the processor is further configured to, in response to the estimated sleep depth of each of the plurality of occupants being greater than the predetermined reference depth, control the reclining mechanism to increase the angle between the seat back and the seat cushion as compared with a case where the estimated sleep depth of the at least one occupant is equal to or lower than the predetermined reference depth or the at least one occupant is awake.

7. The vehicle control device according to claim **1**, wherein

the processor is further configured to, in response to the estimated sleep depth of each of the plurality of occupants being greater than the predetermined reference depth, control the vehicle such that the magnitude of the external force to each of all of the plurality of occupants is equal to or less than the second threshold value larger than the first threshold value, while allowing the magnitude of the external force to be larger than the first threshold value.

8. The vehicle control device according to claim **1**, wherein

the processor is further configured to control a brake device of the vehicle such that the magnitude of the external force to be applied to the at least one of the plurality of occupants is equal to or less than the second threshold value greater than the first threshold value.

9. The vehicle control device according to claim **8**, wherein

the processor is further configured to predict the external force based on at least one of radius of curvature of a road, an inclination angle of the road, or an uneven portion of a road surface of the road, the radius of curvature and the inclination angle being obtained from at least one of image data obtained by capturing an

image of the road on which the vehicle travels and map information including information on the road.

10. The vehicle control device according to claim **9**, wherein

the processor is further configured to

predict a centrifugal force to be applied to the at least one occupant as the external force based on the radius of curvature; and

move the seat in a same direction as the centrifugal force along a width direction of the vehicle.

11. The vehicle control device according to claim **10**, wherein

the seat includes

a seat cushion configured to support a waist of the occupant,

a seat back that is rotatably supported by the seat cushion and is configured to contact with a back of the occupant, and

a reclining mechanism for adjusting an angle of the seat back with respect to the seat cushion, and

the processor is further configured to

predict the external force to be applied to the at least one occupant due to the inclination angle of the road; and

control the reclining mechanism to rotate the seat back in a same direction as a direction of the external force due to the inclination angle.

12. The vehicle control device according to claim **11**, wherein

the processor is further configured to, in response to the estimated sleep depth of each of the plurality of occupants being greater than the predetermined reference depth, control the reclining mechanism to increase the angle between the seat back and the seat cushion as compared with a case where the estimated sleep depth of the at least one occupant is equal to or lower than the predetermined reference depth or the at least one occupant is awake.

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